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Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

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(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Foil display

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Foil display

The present invention relates to a display device comprising a light guide, a back plate, a flexible element arranged in between said light guide and said back plate, and addressable electrodes for inducing electrostatic forces on said element and to bring selected portions of said element into contact with said light guide, in order to extract light from said light guide.

Such displays are normally referred to as foil displays.

A conventional foil display (see e.g. WO00/38163) comprises a light guide in the form of an edge lit glass plate and a non-lit back plate, with a scattering foil clamped in between. On both plates there are respective sets of parallel electrodes which are arranged perpendicularly with respect to each other. By application of voltages to appropriate electrodes on the light guide and the back plate it is possible to generate two electrostatic fields with the field vectors directed towards the light guide and the back plate respectively. The balancing of these two electrostatic forces in combination with the elastic force of the foil is used to attract the foil to either the light guide or the back plate. Typically, the foil can be attracted towards the light guide using a column electrode and towards the back plate using a row electrode.

Because the attractive force (Coulomb force) towards each of these electrodes is proportional to the inverse of the "effective" distance between the respective electrode and the foil conductor (i.e. taking into account the the dielectric constant of the layers between the electrode and the foil conductor), there is a hysteresis in the switching behavior. This hysteresis accounts for a bi-stable region: If pixels are not selected by a row voltage, they will not switch – independent of the voltage on the column electrode. Because such a bi-stable region exists there is a memory effect in the pixels, and therefore a passive matrix addressing scheme can be used to drive the display.

A crucial feature of the conventional foil display are sets of matching spacers on both plates. In between these spacers the foil is clamped, and a gap is defined between the foil and the two plates:

Shortcomings of the currently observed performance with the above outlined design are:

- requirement for high addressing voltages, foil voltage typically 50-80V, select pulses on row and column electrodes approximately 10–20V.
- large number of unwanted pixel switching events during addressing.

The object of the present invention is to overcome these shortcomings, and to provide a foil display having an improved addressing of the flexible element.

According to the invention, this object is achieved by a foil display of the kind mentioned by way of introduction, wherein only one of the light guide and the back plate is provided with addressing electrodes, and wherein a biasing force acts on the flexible element in a direction away from said addressable electrodes.

Note that the biasing force acts on essentially the entire flexible element. The addressing electrodes are each capable of addressing a portion of the flexible element, such as an individual pixel or a row of pixels, and to create an electrostatic force on this portion, locally overcoming the biasing force.

However, the flexible element now only needs to be displaced between two positions, instead of as in the conventional foil display, between two extreme positions with a bi-stable position in between.

As the bi-stable position is not required for the addressing of the display, the foil display layout can thus be optimized to minimize the bistable region and to be compatible with active matrix addressing (see below). Consequently, the voltages required to operate the display will also be lower compared to the conventional foil display. In principle it is feasible to keep the electrode of the flexible element at ground potential while applying 10-20V pulses to the addressable electrodes to overcome the biasing force. For these voltage ranges the driver electronics is simpler, and likely to be commercially available.

Preferably, active matrix addressing is used to address the addressable electrodes.

Figure 1 shows a switching curve of a conventional foil display. An “ON”-curve 1 and an “OFF”-curve 2 define a bi-stable region 3 in between them, e.g. an area of hysteresis. This is a required condition for passive matrix addressing, and the operating area (points 4 and 5) has to be chosen in this bi-stable region 3. A change of column voltage alternates the pixel between the points 4 and 5, without switching state. In order to switch the pixel ON, the row voltage must be set low (closer to the foil voltage) and the column voltage

must be set high (point 8). Conversely, in order to switch the pixel OFF, the row voltage must be set high, and the column voltage set low (point 9). Alternatively, the pixel is turned OFF by setting the column voltage even lower than in point 4, a so called robust switch off. In any case, it is clear from fig 1 that three levels are required on either the column or row driver. Further, several foil positions are located in the bi-stable region, and the performance is sensitive to pixel spreading and charging.

In using active matrix addressing the pixel memory is instead provided by the pixel circuit. If a select pulse is given, a voltage can be stored on the pixel circuit, which defines whether a pixel is switched "on" or "off". Thus only two levels are needed, one in the ON region (i.e. below both the ON curve 1 and the OFF curve 2), and one in the OFF region (i.e. above the ON curve 1 and the OFF curve 2). As a consequence, the drivers can be simplified.

Also, an increase in the pixel spread will only lead to a larger voltage swing of the drivers, but not to non-addressable pixels, which is a risk with PM addressing. Even horizontal (i.e. the switching is independent of the row voltage) or vertical (independent of the column voltage) switching curves would offer good performance. Since the operating point can be chosen freely, a small voltage swing and a good pixel filling should be aimed for.

An additional advantage is that the addressing pulse length can be substantially reduced with AM addressing. In PM addressing the pulse has to be maintained on the electrodes during the time necessary to switch the foil between the "off" and the "on" state. In AM addressing, the voltage can be written on the pixel circuit, which will then maintain the correct voltage difference between the electrodes and induce switching. In other words, the next row of pixels can already be addressed while the first row is crossing over from "off" to "on".

In a foil display, the electrodes on the two plates and on the foil are very close (μm-distance), thus the pixels have a considerable capacitance. With a PM-addressing scheme, the entire column (or row) of capacitances are charged when the voltages on the electrodes are changed. In AM-addressing, the power consumption can be significantly reduced since only the pixels that are addressed are being charged. Depending on the addressing scheme and the gray scaling method, the number of pulses can be reduced, which also leads to lower power consumption.

Another advantage is that because AM-addressing is more robust than PM-addressing, analogue gray scaling – or partly analogue gray scaling – becomes feasible.

According to the invention, addressing electrodes are only required on either the light guide or the back plate. However, an unstructured electrode may be provided on the other plate (light guide or back plate, depending on where the addressable electrodes are arranged), in order to provide a biasing force in the form of a constant electrostatic force acting on the flexible element. The electrostatic force created by the addressable electrodes is then adapted to overcome this attraction, and to pull the foil towards the addressable electrodes.

According to a preferred embodiment, the biasing force is a mechanically induced force, for example an elastic force created by simply removing any spacers between the flexible element and the plate without addressing electrodes. The electrostatic force created by the addressable electrodes is then adapted to overcome this elastic force.

By thus completely eliminating the electrode from the second plate (light guide or back plate, depending on where the addressable electrodes are arranged), the foil is not subjected to any electric field between the electrode layer and this plate, thus avoiding any electrostatic charging phenomena. Also, the balance of two large electrostatic forces for the foil control, requiring higher drive voltages, is avoided. It is further likely that the spread of the switching characteristics can be reduced.

The addressing electrodes are preferably arranged on the back plate. The biasing force can then force the flexible element into contact with the light guide, and the addressing electrodes can be used to release selected portions of the element from the light guide, thereby turning them OFF.

When the addressing electrodes are placed on the back plate, this causes minimal losses of the light guide, and a higher brightness and uniformity can be achieved. This advantage is of particular importance when the flexible element is mechanically biased against the light guide (see above), as then no electrode layer at all is required on the light guide.

Further, the distance between the back plate and the flexible element, and hence between the two plates, can be chosen larger, as there is no need for the flexible element to make contact with the addressing electrodes. With an increased cell gap between the light guide and the back plate the design is less sensitive to trapped dust particles. This in turn will reduce the requirements on the required clean room facilities for the fabrication of the display. It is important to note however that an increased spacer height requires a higher voltage difference in order to release the foil from the light guide.

Instead of, or in combination with, the increased distance between flexible element and back plate, an elastic layer can be arranged between the flexible element and the

back plate, in order to press the element against the light guide and to thereby improve contact between them. The elastic layer further avoids large displacements of the flexible element from the light guide plate, as a complete crossing from the light guide plate to the back plate does not occur. A displacement bringing the foil outside the evanescent field of the light guide plate is sufficient to prevent scattering of light out of the light guide. Consequently, the collision impact of the foil onto the light guide plate that accompanies a pixel switching into the "on" state is much reduced, thus reducing the occurrence of wear and tribo-charging.

The elastic layer between the flexible element and the back plate (and thus the spacers on the back plate) can be made several micrometers thick. This decreases the sensitivity of the foil switching in a pixel to the presence of small contaminant particles on the foil and/or on the back plate surface facing the foil.

Alternatively, the addressable electrodes are arranged on the light guide. The flexible element is then biased away from the light guide, and the addressable electrodes are used to bring it into contact with the light guide, thereby turning the pixel ON.

In this case, the attractive force of the electrodes thereby secure good optical contact between the flexible element and the light guide. In order to shield the light guide from any optical losses, a reflective layer can be arranged underneath the electrodes.

These and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing currently preferred embodiments of the invention.

Fig. 1 illustrates the switching principles of a pixel in a foil display of conventional kind.

Fig. 2 schematically shows a cross section of a first embodiment of a display device according to the invention.

Fig. 3 schematically shows a cross section of a second embodiment of a display device according to the invention.

Fig. 4 schematically shows a pixel circuit suitable for a display device according to the invention.

Fig. 5 schematically shows a cross section of a third embodiment of a display device according to the invention.

Fig. 6 schematically shows a cross section of a fourth embodiment of a display device according to the invention.

Fig. 7 schematically shows a cross section of a fifth embodiment of a display device according to the invention.

Fig. 8 schematically shows a cross section of a thin film transistor (TFT) implemented in a foil display according to fig 2.

Figure 2 shows a foil display device 11 according to an embodiment of the invention. The display comprises a light guide (active plate) 12, connected to a light source 13, such as a LED, a back plate (passive plate) 14, and a flexible element clamped in between these plates. The flexible element can be a foil 15 of a flexible, light scattering material, such as parylene, with an unstructured electrode layer 16 disposed thereon. Spacers 17 are arranged between the back plate 14 and the foil 15, but contrary to a conventional foil display, no spacers are required on the other side of the foil. As a result, the foil 15 is pushed against the light guide 12. The design of the spacers 17 and the light guide 12 in the areas of contact 18 are optimized to achieve a large elastic force directed towards the light guide. In the illustrated example the light guide 12 has indentions 19 receiving the spacers 17, to thereby create a suitable elastic force. Further, at the places 18 where the spacers 17 keep the foil in contact with the light guide 12, a reflecting layer 20, of e.g. aluminum or silver, can be arranged.

Good optical contact between the foil 15 and the light guide 12 is achieved through van der Waals adhesion. The magnitude of this adhesion can be tuned through an appropriate adjustment of both the surface density of scattering particles that protrude from the foil surface facing the light guide, and the protrusion distance from the foil. Also the deformation characteristics of the light guide surface plays a role in this regard.

The back plate 14 is provide with addressing electrodes 23, arranged to be capable of applying a positive voltage to a pixel element of the back plate 12. The electrodes can be formed by a transparent ITO layer, covered by an insulating layer 24. The foil electrode 16 is connected to ground potential 25. The addressing electrodes 23 are addressed by addressing means 26, which will be described more in detail below.

As the foil is held in contact with the light guide, each pixel has a default state of ON. When an appropriate voltage difference is applied between the foil electrode and the corresponding addressing electrode, an electrostatic force is generated between the

addressing electrode and the foil, which overcomes the elastic force and releases the foil from the light guide. The pixel is thus turned OFF. The movement and position of the foil is controlled by the balancing of the elastic force and the electrostatic force. A local non-contact area (not shown) can be provided between the foil and the light guide within the pixel confinement area, to ensure that the foil releases from the light guide in a lateral peeling process. Local outcoupling of light from the light guide by the foil at those positions 18 where the foil is permanently clamped onto the light guide through the presence of spacers 17 on the back plate is prevented by the specular-reflective patches 20.

A possibility for gray scales generation comes from the modulation of the amplitude of the voltage pulse imposed on the pixel electrodes, as this affects the width of the optical contact area of the foil on the light guide, and thereby the intensity of the emitted light. Generally speaking, gray scales can be obtained by a combination of pulse width modulation (time modulation) and pulse height modulation (foil/light guide contact area modulation).

According to a further embodiment, illustrated in fig 3, an elastic layer 31 is arranged in between the foil and the addressing electrodes.

The elastic layer 31 can be made of a spongy organic material with an open cell structure and a high (> 80%) porosity. At a thickness of a few µm, the pressure required to contract this layer by about 100 nm should be comparable to that of deflecting the foil 15 by about 100 nm in a given pixel confinement and thus spacer pitch.

According to this embodiment, the final location and shape of the foil results from the balance between the applied electrostatic force on the one hand and the opposing elastic force in the compressed porous layer and the elastic force in the foil on the other hand. In case the separation between the foil and the light guide is made to exceed a few hundred nm, no light is locally extracted and the pixel is in the "off" state. In case the separation between the foil and the light guide plate is adjusted between 30 nm and 100 - 150nm, the evanescent field of the light guide only partly couples with the foil medium, thus creating the possibility of analogue gray scale formation.

As the elastic layer 31 provides insulation between the addressable electrodes 23 and the foil electrode 16, no insulation layer 24 is required.

The addressing electrodes 23 in figs 2 and 3 are preferably addressed by means of active matrix addressing. Such addressing may be provided by means of thin film transistor (TFT) switches 35 arranged on the back plate 14 and connected to each addressing electrode 23, as illustrated in fig 8. The TFT 35 shown in fig 8 is a bottom gate TFT. The

TFT has two source drain electrodes 36, 37 and a bottom gate electrode 38. The first electrode 36 is connected to the transparent pixel electrode 23, the other electrode 37 is connected to a power line (not shown in fig 8). An insulating layer 39 covers the bottom gate 38, while the insulating layer 24 covers the entire TFT 35 and electrode structure 23.

The area of a foil display pixel is typically 200um by 600um - three pixels make a RGB pixel. The area covered by the TFT 35 is very small compared to the pixel area, approximately about 2% in a typical case. The height of the TFT stack 35 is approximately 500nm, which is about half of the height of the spacers 17. It is thus possible to place the TFTs 35 in such a way (e.g. in the corner of a pixel) so as to not affect the optical performance dramatically. As will be mentioned below, the TFT 35 may be placed either on the active or on the passive plate (light guide or back plate).

As mentioned above, AM addressing can make very fast addressing possible. However, if only a TFT-switch per pixel is used without a power-line, due to the capacitance change of the pixel when crossing from the "off" to the "on" state, such fast addressing is not possible. Figure 4 shows a pixel circuit more suitable for the display according to the invention.

The circuit 40 comprises two drive transistors 41, 42 of different type, i.e. PMOS and NMOS, having their drains connected to the pixel capacitance 43, i.e. the addressing electrode. The transistor sources are each connected to a different power line 44, 45, the first carrying a zero voltage, the second carrying a positive voltage, e.g. 20 V. The gates of the transistors 41, 42 are connected to the drain of a selection transistor 47, the gate of which is connected to a row selection line 48. The source of the selection transistor is connected to a column data line 49. Further, a first capacitor 51 is provided between the drain of the selection transistor 47 and the positive voltage power line 45, and a second capacitor is provided between the drain of the selection transistor 47 and the grounded power line 44.

Rows are selected with a 40V pulse on the row selection line 48, enabling writing of data on the column data line 49 to point B. Two capacitors 51 and 52 are used to fix the voltage level at point B. Through the combination of a PMOS and NMOS switches, the voltage is sourced or sunk from the two corresponding power lines 44, 45 to point A. In the illustrated example, a high signal on the column data line results in a low signal in point A. The same function can be realized by a complimentary circuit replacing PMOS with NMOS and NMOS with PMOS. Proper choice of the row voltage levels is necessary.

The circuit of fig 4 can be implemented in a CMOS circuit. In order to simplify the circuit, and to allow implementation with amorphous silicon technology, a two

transistor circuit, known per se, can be used. The TFT in fig 8 is an example of such an implementation. Compared to the circuit in fig 4, components 51, 45 and 41 are removed. Further, arrangements must be made to allow for external switching of the power line 44 between different values.

Before frame inversion, a reset pulse has to be given to all pixels. Inclusion of frame inversion in the driving scheme is possible, but adds complexity. Grayscales can be achieved with pulse width modulation.

According to the above embodiments, the addressing electrodes 23 and TFTs 35 are arranged on the back plate 14, while the light guide 12 has no electrodes. This limits the optical disturbance of the light guide. However, a potential draw back is that the TFT has to be processed on the color filter plate (which requires planarization) or below it (which requires higher voltages).

According to a further embodiment, shown in fig 5, the design of the display in fig 2 is reversed. In other words, the addressing electrodes 23 (and TFTs 35) are arranged on the light guide 12, and spacers 17' are arranged to separate the foil 15 from the light guide 12.

The foil 15 does not have to make contact with the back plate 14, even though this is the case in the illustrated example. According to this embodiment, the default state of a pixel is OFF. By applying a voltage difference between the addressing electrodes and the foil, the elastic force is overcome, and the foil 15 is attracted to the light guide 12, to turn the pixel ON. The electrostatic force itself will ensure satisfactory contact between the foil 15 and the light guide. In this case, a reflective layer, such as an Al layer, can be arranged underneath the TFTs 35, in order to minimize optical losses. This has been indicated by numeral 32 in fig 8, in the case where the TFT 35 is arranged on a light guide 12. Note, however, that the layer 32 in fig 8 is illustrated as extending into the glass plate 12, while it in reality would be disposed on top of the glass plate 12, leading to a slight displacement of the TFT stack 35.

According to still another embodiment, the biasing force acting on the foil is also an electrostatic force, generated by an unstructured electrode 33 arranged on the opposite side of the foil. The electrode, e.g. an ITO layer 33, is covered by an insulating layer 34. In fig 6, such an unstructured electrode 33 is arranged on the light guide 12, and in fig 7 it is arranged on the back plate 14. In both cases, spacers (not shown) can be arranged on both sides of the foil 15, as there is no longer a need to create the elastic force mentioned above. In fig 7, the back plate 14 consists only of a color filter with unstructured ITO. Such color filters with unstructured ITO are readily available from external suppliers.

The present invention is not limited to the above description of preferred embodiments. On the contrary, the skilled man realizes that there numerous modifications and alternatives are possible within the scope of the appended claims. For example, instead of active matrix addressing, the display can be addressed line at a time, by arranging the foil to extract light from the light guide one row at a time. By arranging for amplitude modulation of the light guide, such an addressing scheme can also be implemented to achieve gray scaling. The details of such an addressing scheme are disclosed in PHNL021414 (EP Application number 02080543.8), hereby enclosed by reference.

CLAIMS:

1. A display device comprising a light guide (12), a back plate (14), a flexible element (15) arranged in between said light guide (12) and said back plate (14), and addressable electrodes (23) for inducing electrostatic forces on said element (15) and to bring selected portions of said element (15) into contact with said light guide (12), in order to extract light from said light guide (12), characterized in that said addressable electrodes (23) are arranged only on one of said light guide (12) and said back plate (14), and that a biasing force acts on said flexible element (15) in a direction away from said addressable electrodes (23).

2. A display device according to claim 1, wherein said addressable electrodes (23) are addressed using active matrix addressing.

3. A display device according to claim 0, wherein thin film transistors (TFT) (35) are used to address the electrodes (23).

4. A display device according to one of claims 1 - 0, wherein said element (15) is electrostatically biased away from the addressing electrodes (23).

5. A display device according to one of claims 1 - 0, wherein said element (15) is mechanically biased away from the addressing electrodes (23).

6. A display device according to claim 0, further comprising an elastic layer (31) between the flexible element (15) and the addressable electrodes (23).

7. A display device according to claim 0 - 0, wherein said addressable electrodes (23) are arranged on the back plate (14).

8. A display device according to claim 0 - 0, wherein said addressable electrodes (23) are arranged on the light guide (12).

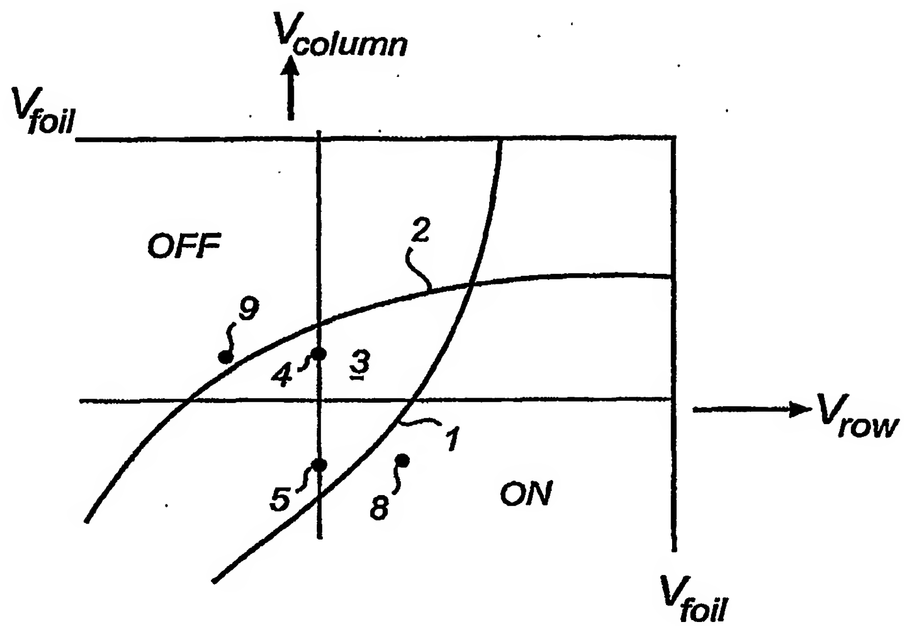
9. A display according to claim 0 when depending on claim 2, wherein a reflective layer (32) is arranged underneath the TFT (35).

ABSTRACT:

A display device comprising a light guide (12), a back plate (14), a flexible element (15) arranged in between said light guide (12) and said back plate (14), and addressable electrodes (23) for inducing electrostatic forces on said element (15) and to bring selected portions of said element (15) into contact with said light guide (12), in order to extract light from said light guide (12). The addressable electrodes (23) are arranged only on one of said light guide (12) and said back plate (14), and a biasing force acts on said flexible element (15) in a direction away from said addressable electrodes (23).

The voltages required to operate the display will also be lower compared to the conventional foil display. In principle it is feasible to keep the electrode of the flexible element at ground potential while applying 10-20V pulses to the addressable electrodes to overcome the biasing force.

Fig. 2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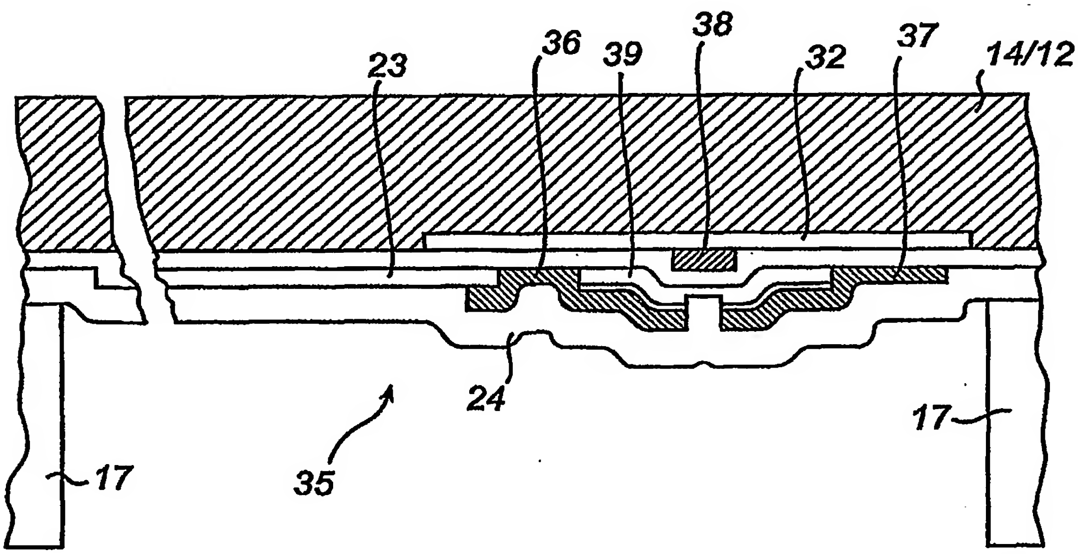
9
4
3
V_{row}
1
5
8
ON
V_{foil}

Fig. 1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36
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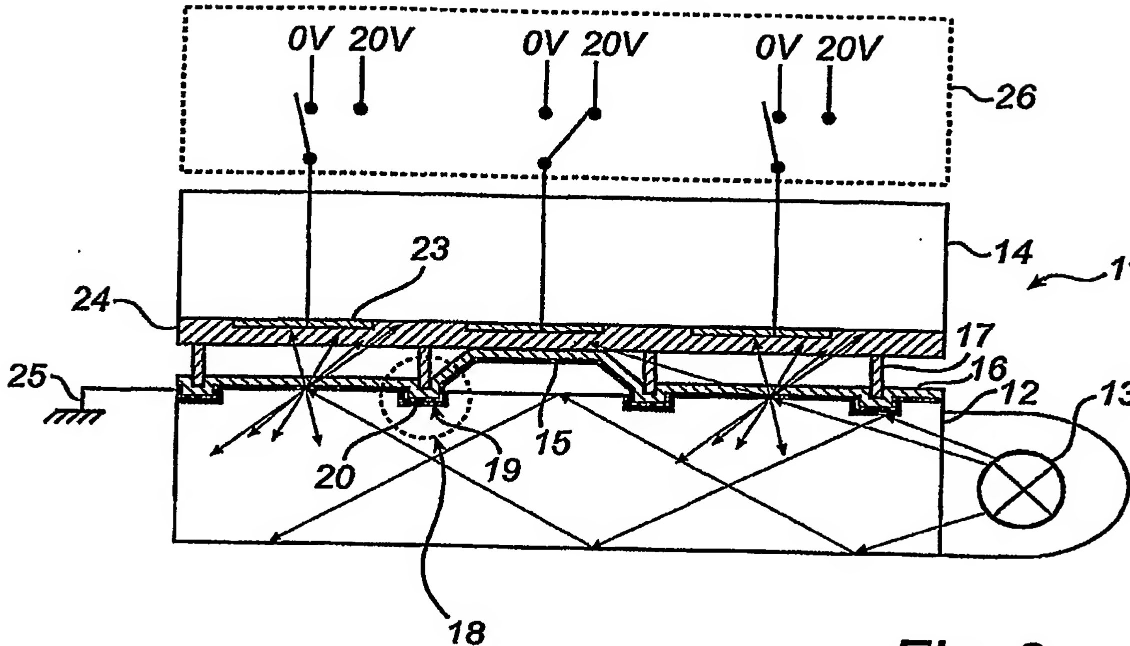
37
23
32
14/12
24
17
35
17

Fig. 8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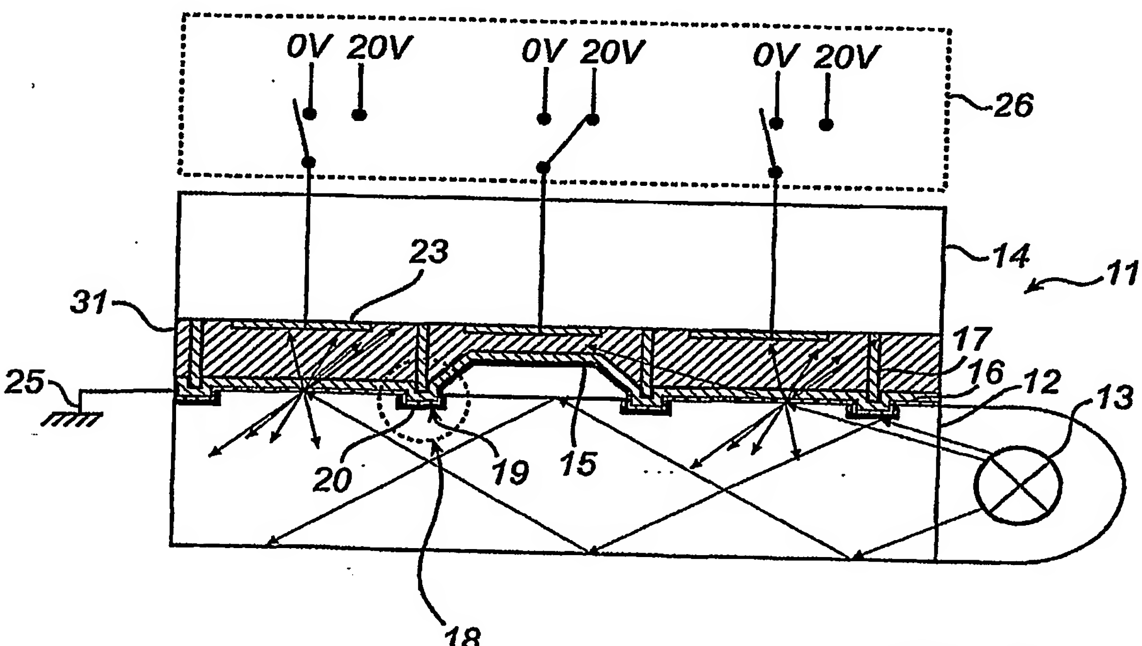
18

Fig. 2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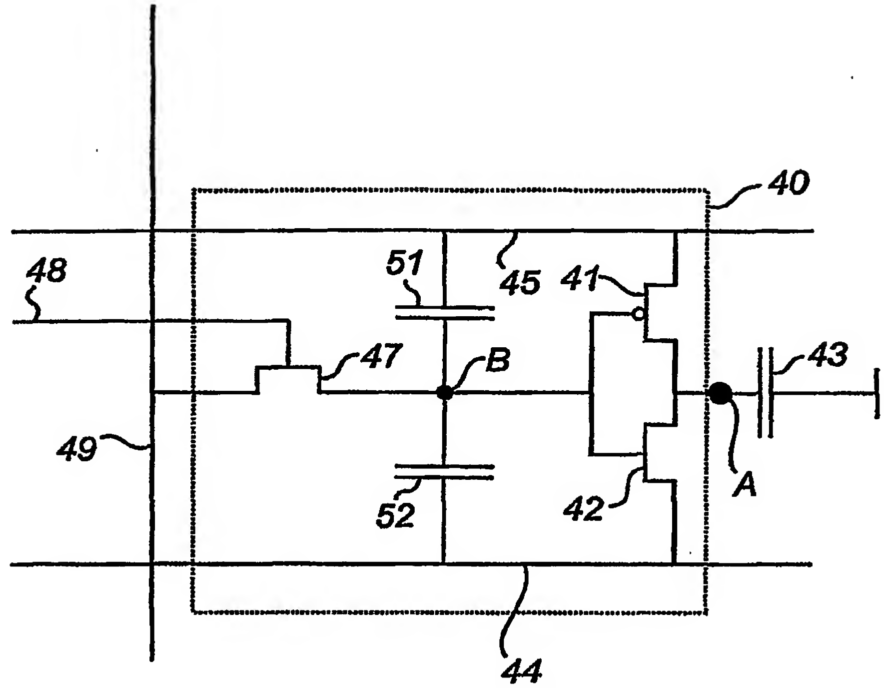
18

Fig. 3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A
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44

Fig. 4

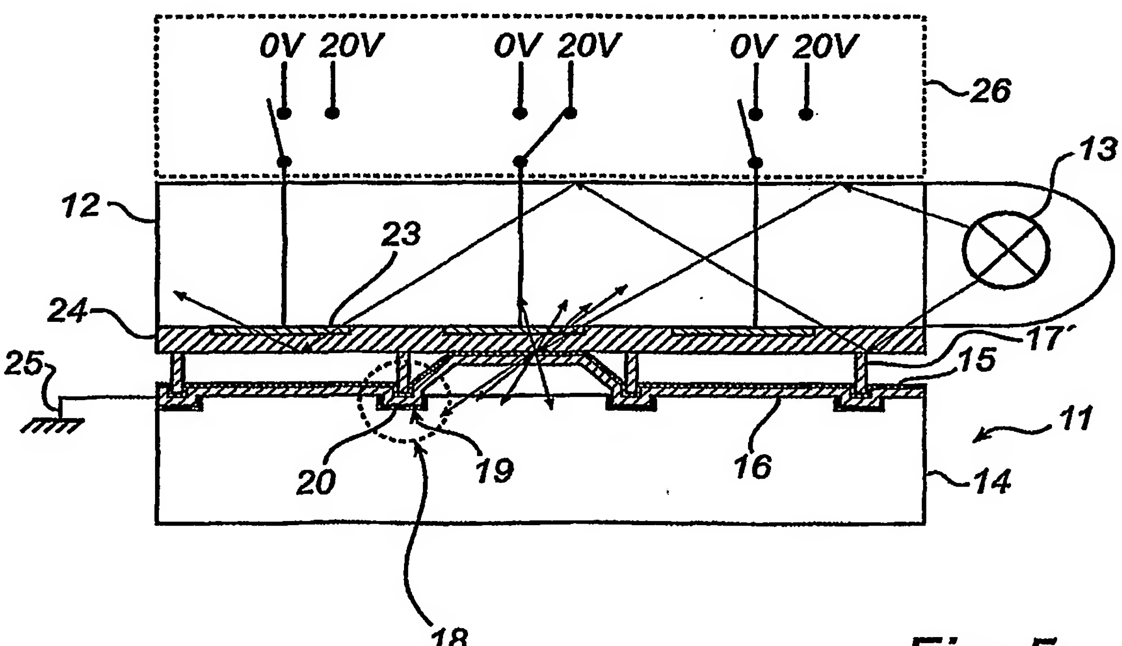
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Fig. 5

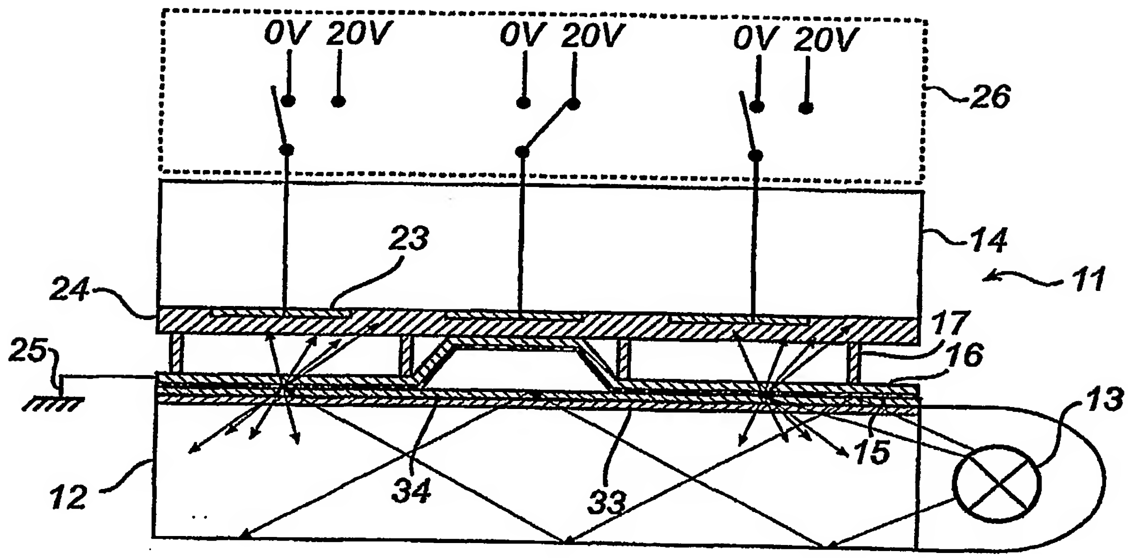
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Fig. 6

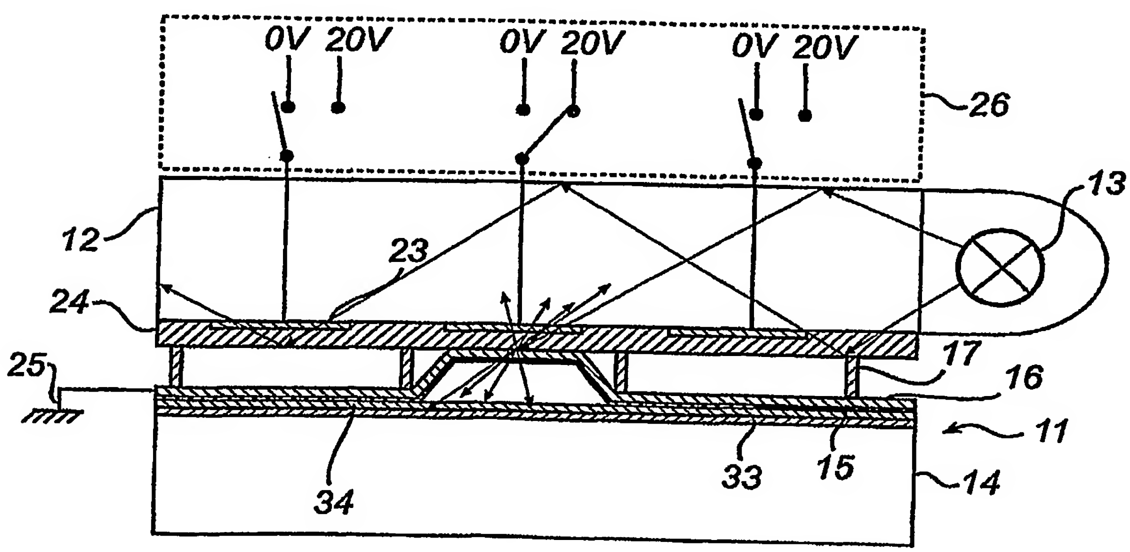
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Fig. 7